

Headquarters U.S. Air Force

Integrity - Service - Excellence

Pragmatic Expectations for Source Zones



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Tom Sale
Colorado State University
1/29/01



Objectives

- Focus our individual site management and research efforts
- Drive a shift towards more pragmatic expectations for management of DNAPL source zones.

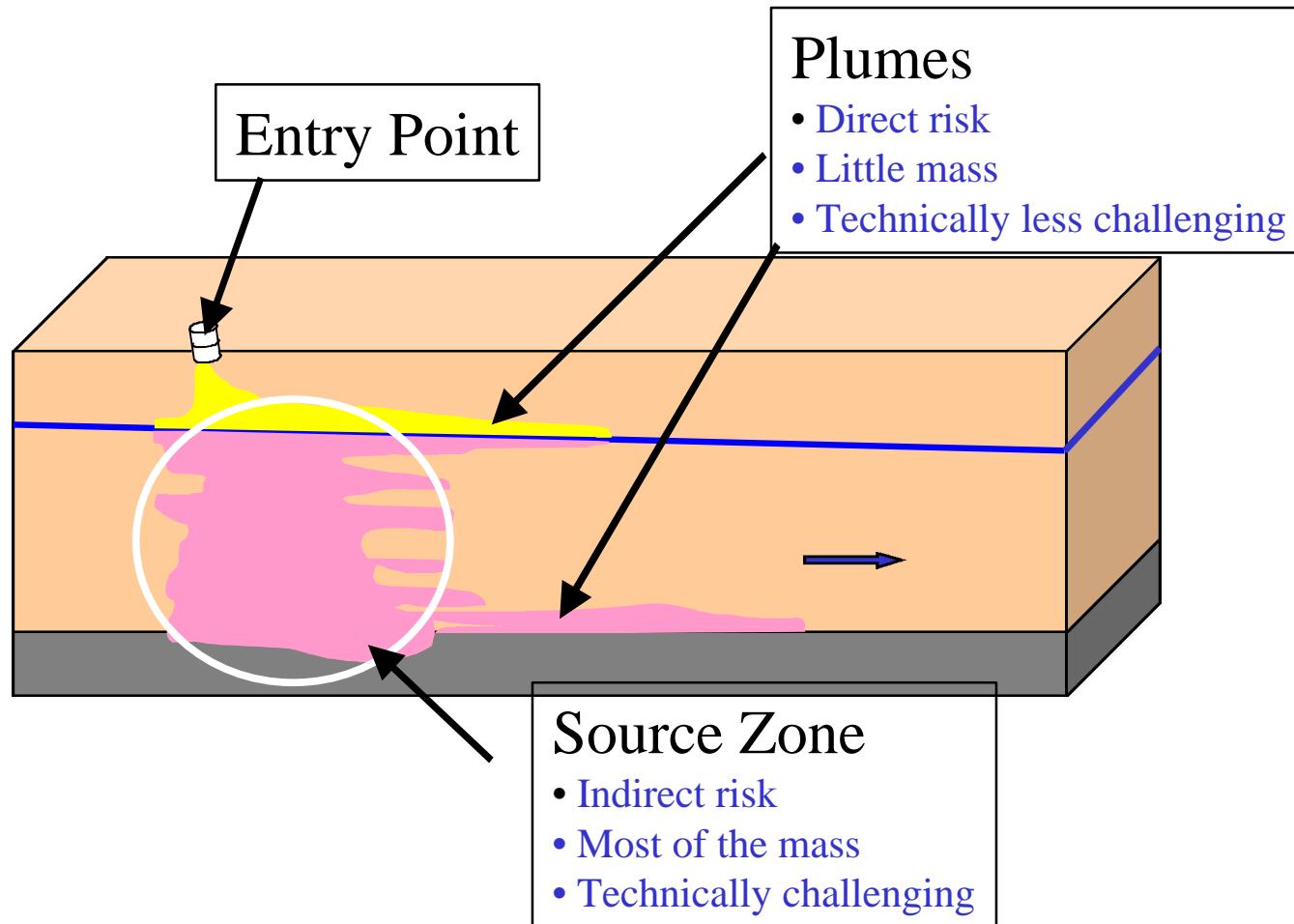


Scope of Presentation

- How efficient does it need to be?
- How efficient can it be?
- What technologies are available?



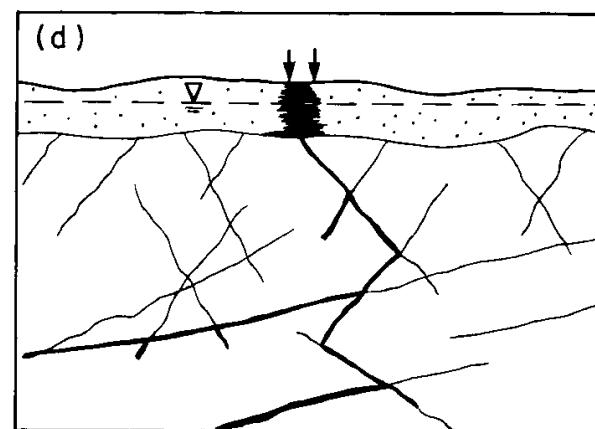
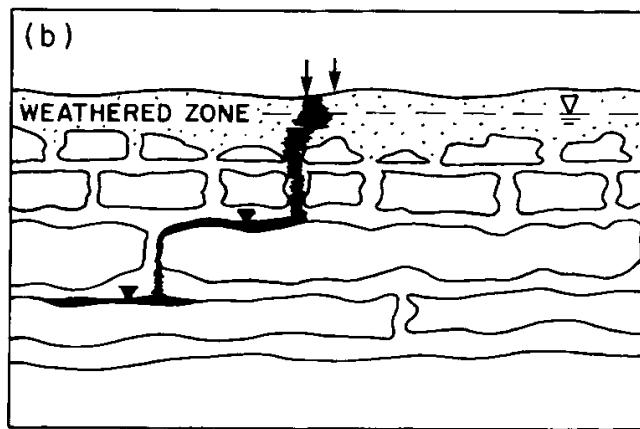
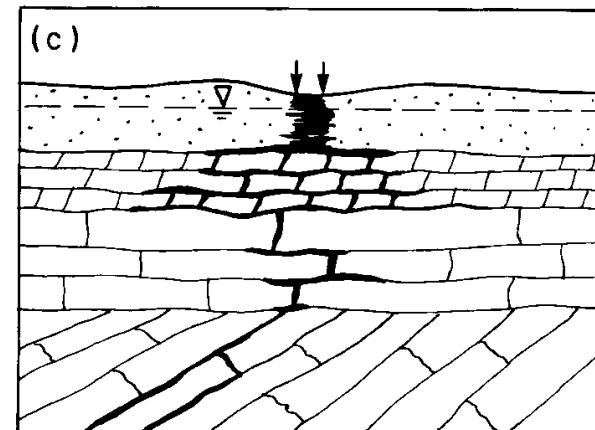
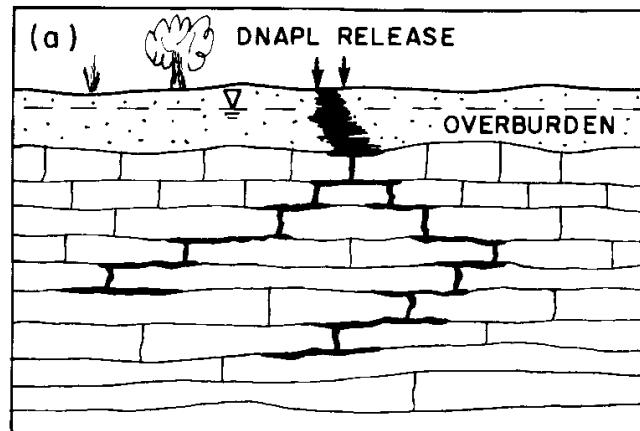
Definitions and Basic Concepts





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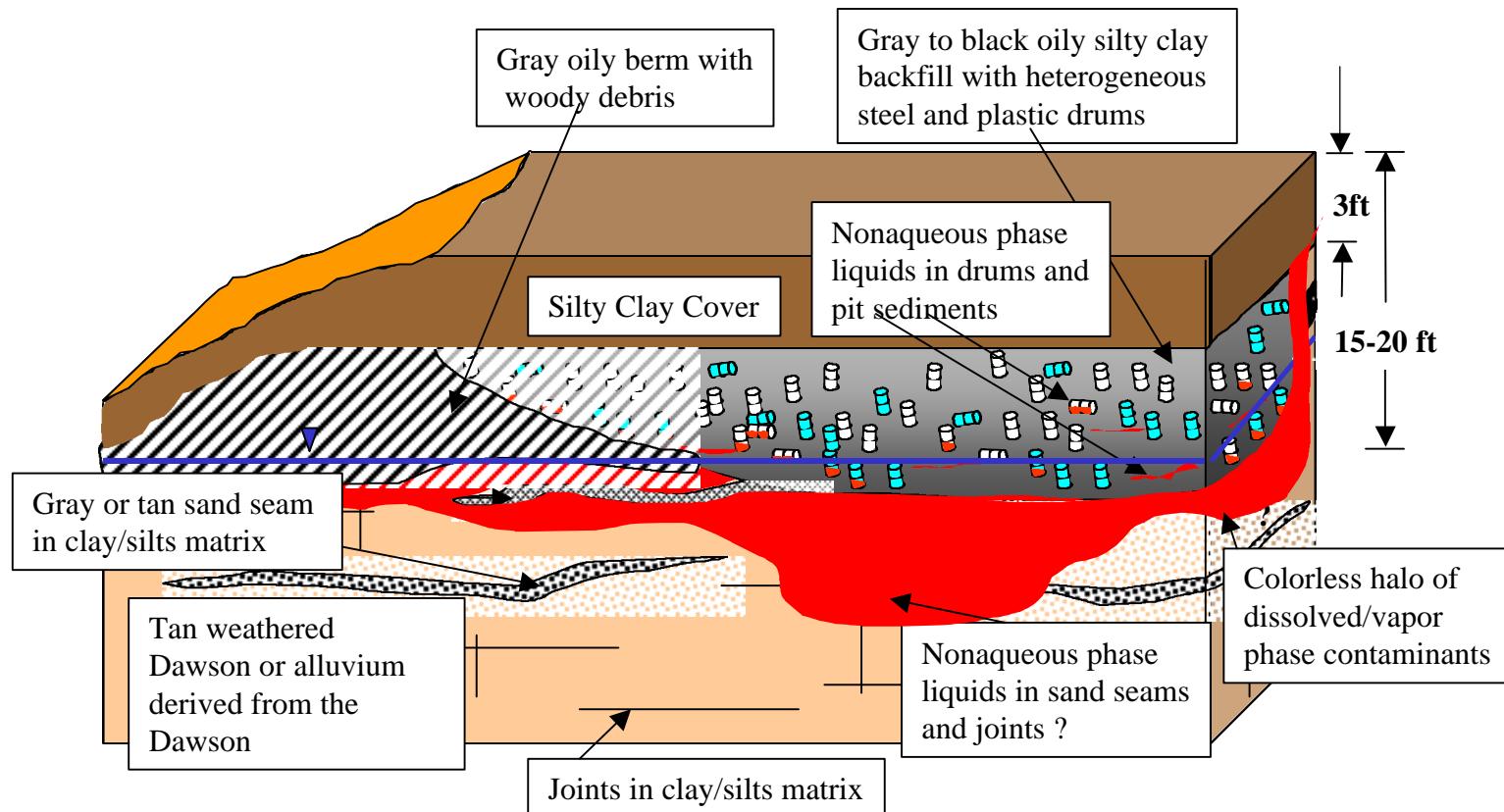
Pankow and Cherry 1996





Conceptual Model

Typical Condition North and South Pit





Remedies

■ Containment

- Active (e.g. Pump and treat)
- Passive (e.g. Zero valent iron reactive barriers)

■ Source Zone Cleanup

- Remediation (meaningless junk term - any mass removal)
- Restoration (Pristine)
- Renovation (To a certain point)



Source Zone Goals

■ Restoration

- MCLs in source zone
- Very high levels of mass removal

■ Renovation

- Reduced site care requirements
- Reduced areal extent of exceedances
- Reduced loading to a receptor

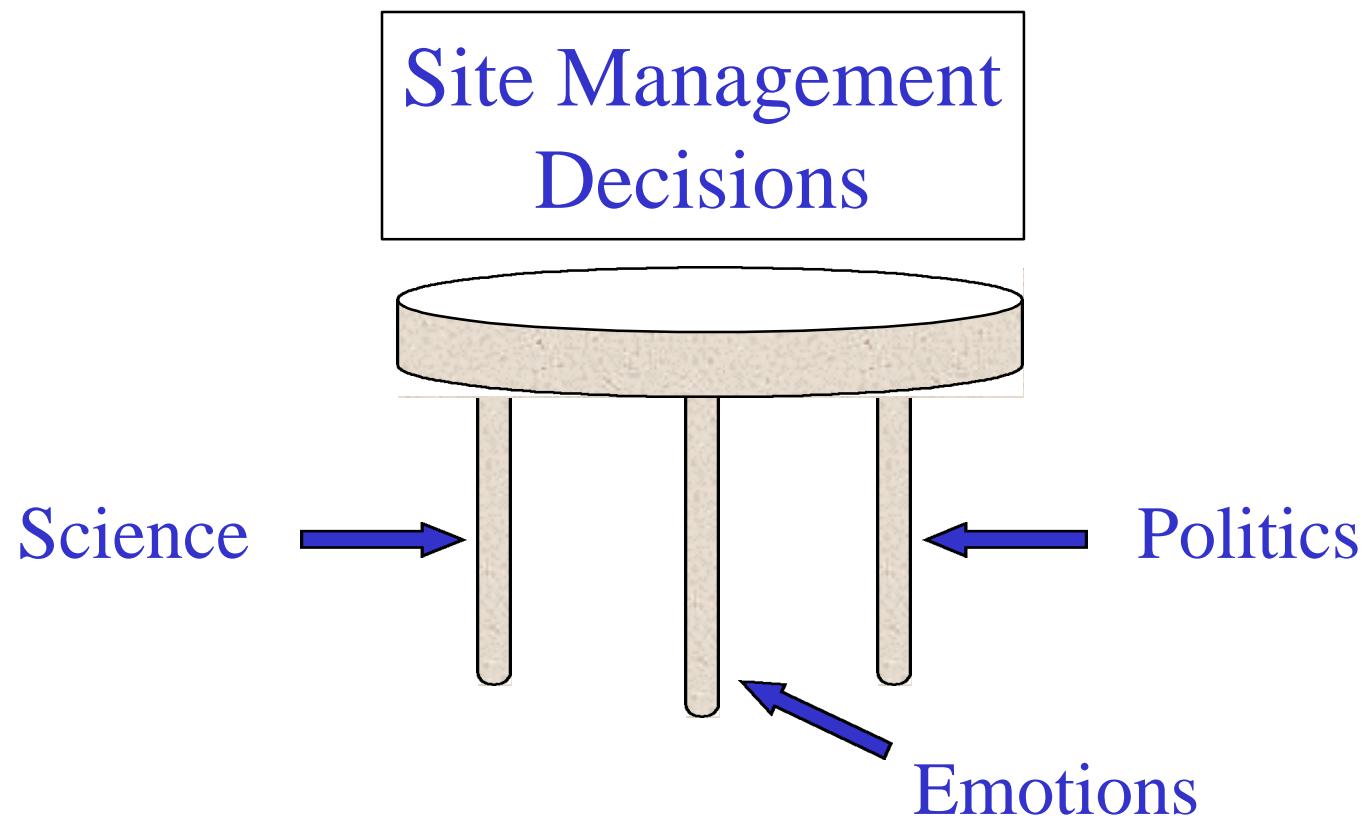


General Source Zone Options

- **Mass Recovery (forced advection)**
 - Chemical mobilization
 - Thermal mobilization
 - Physical recovery
- **Mass Destruction (delivery)**
 - Chemical oxidation
 - Biological degradation
 - Thermal destruction

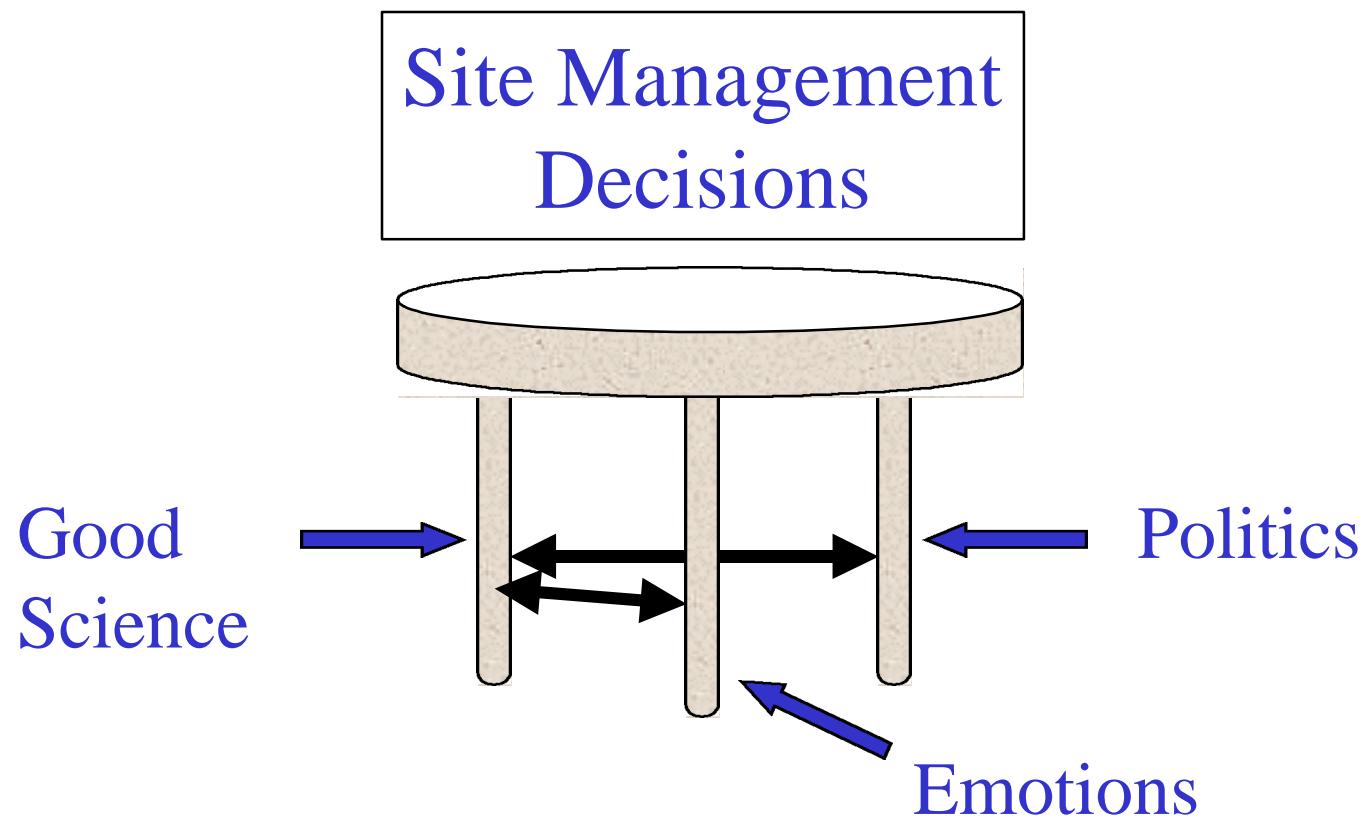


“Good Science” and Decision Making (current condition)



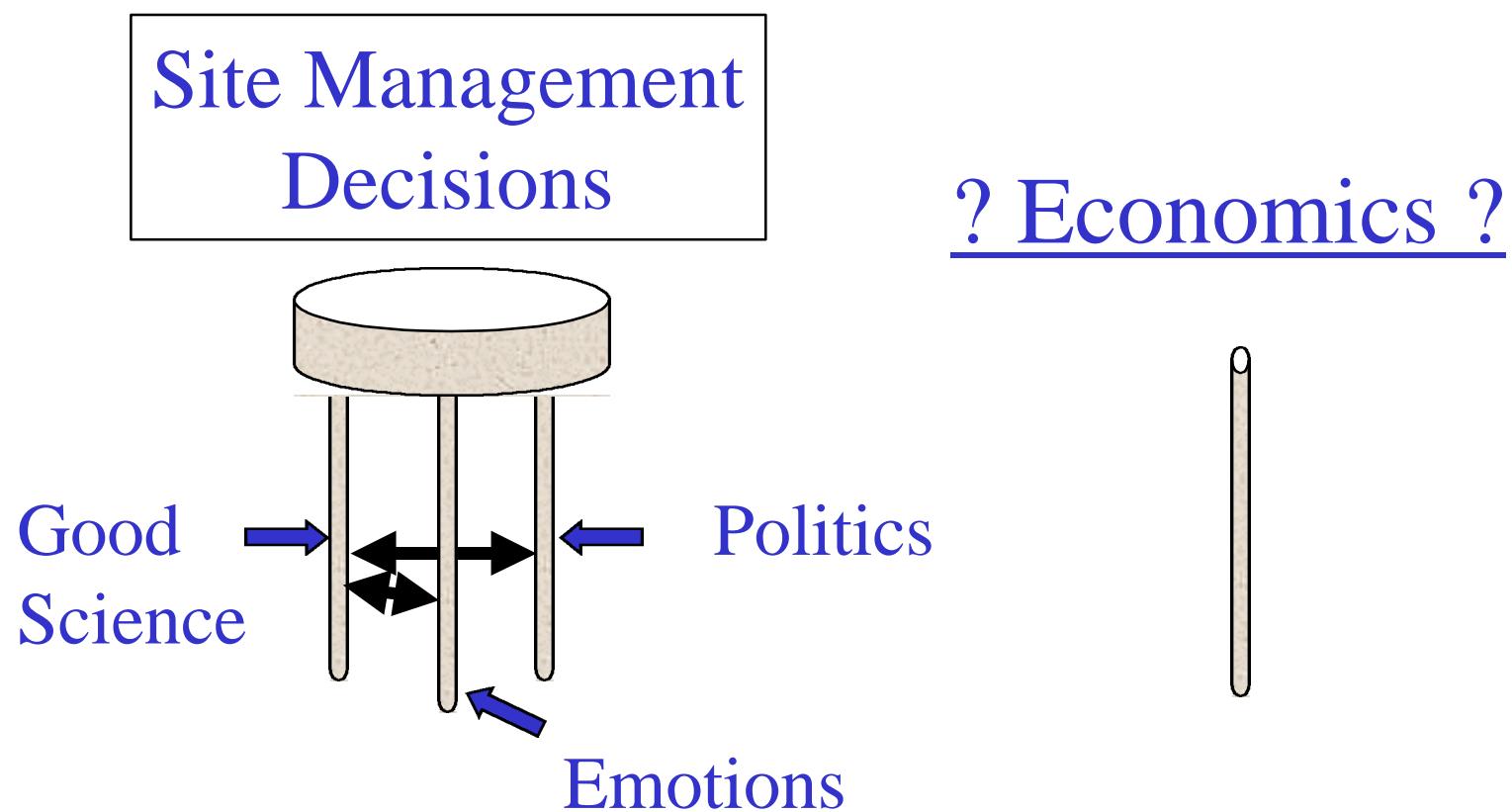


“Good Science” and Decision Making (desired condition)



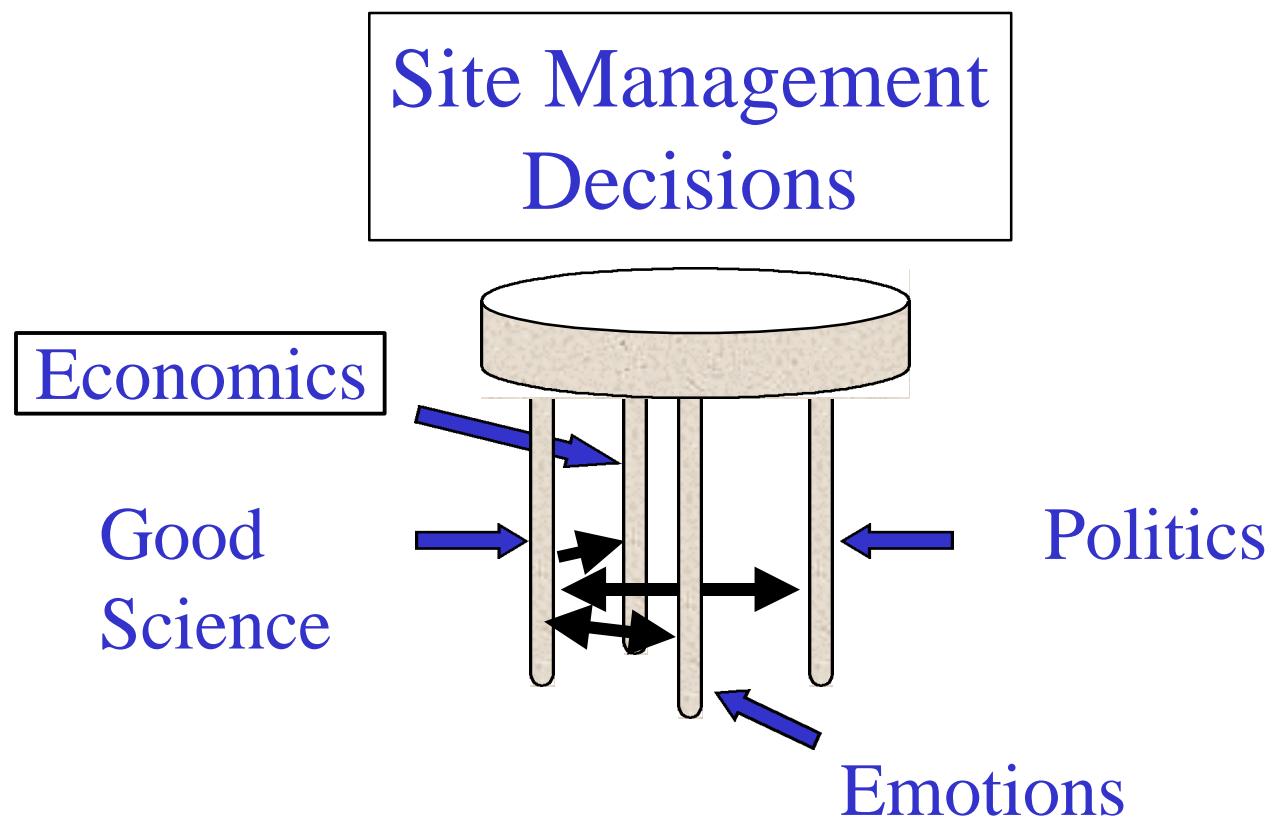


“Good Science” and Decision Making (a missing element?)





“Good Science” and Decision Making (an improved approach)



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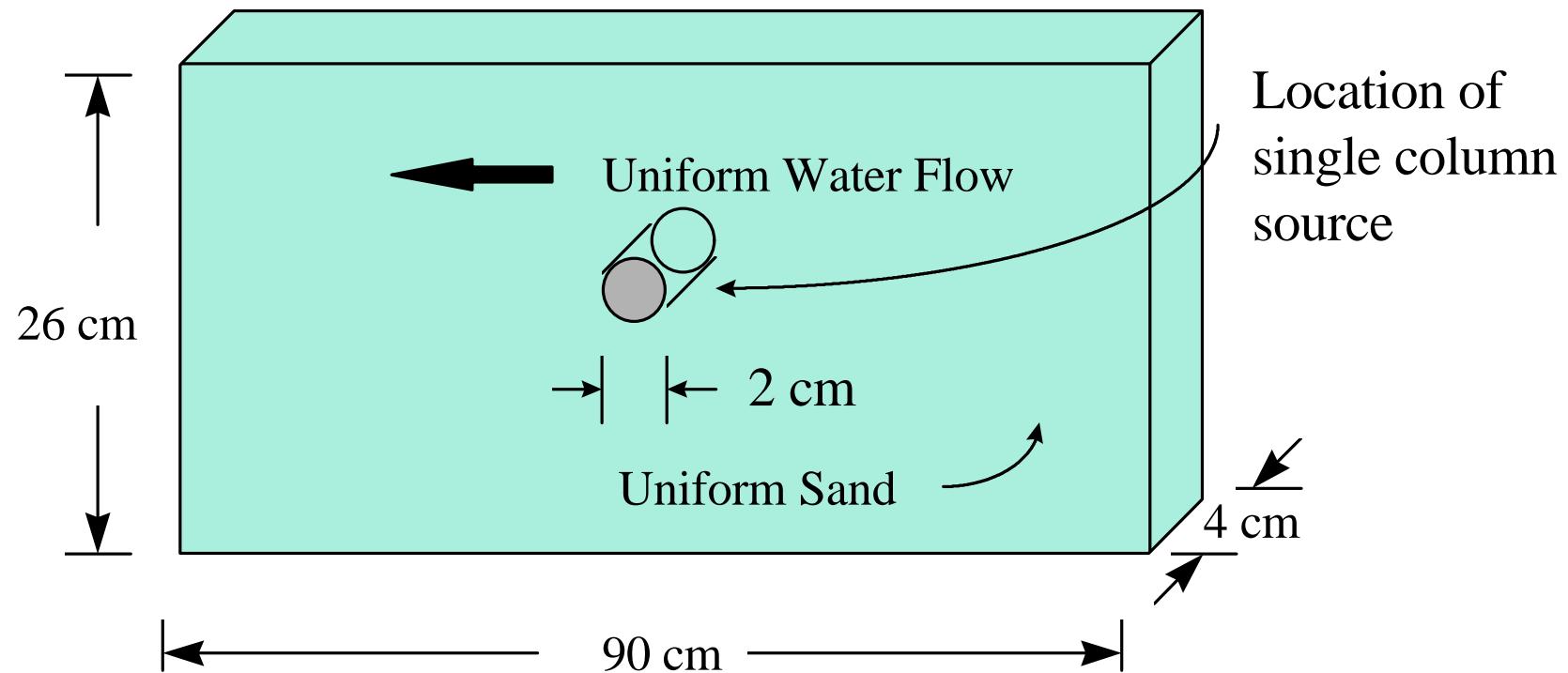
How Efficient Does it Need to Be?



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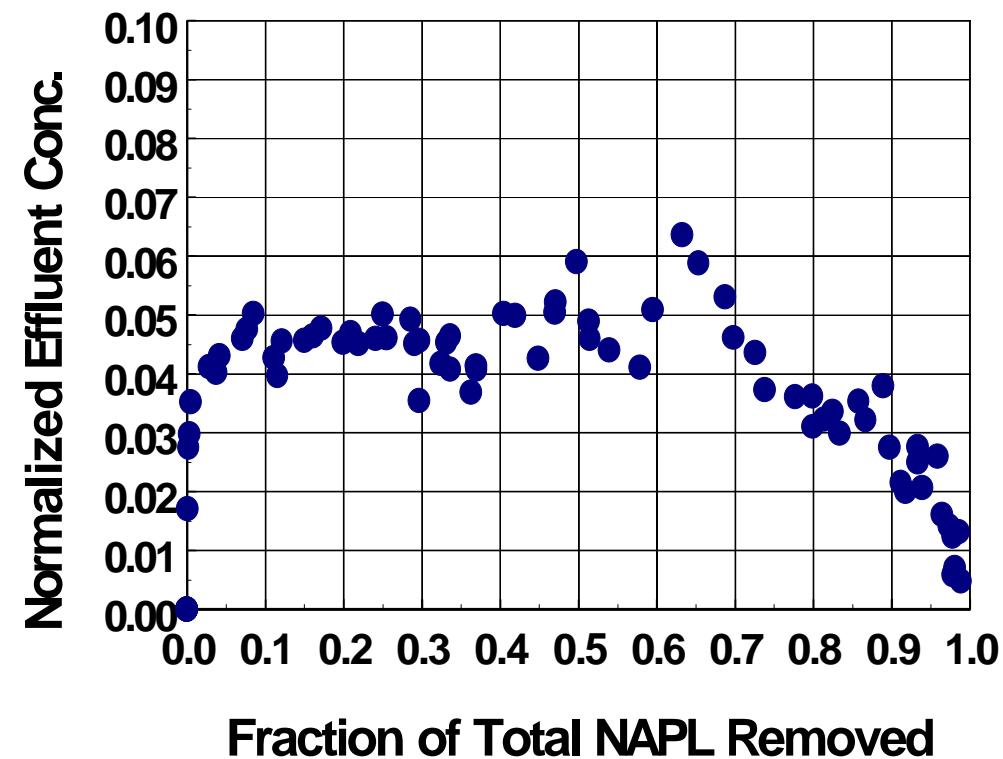


Column Source Laboratory Studies



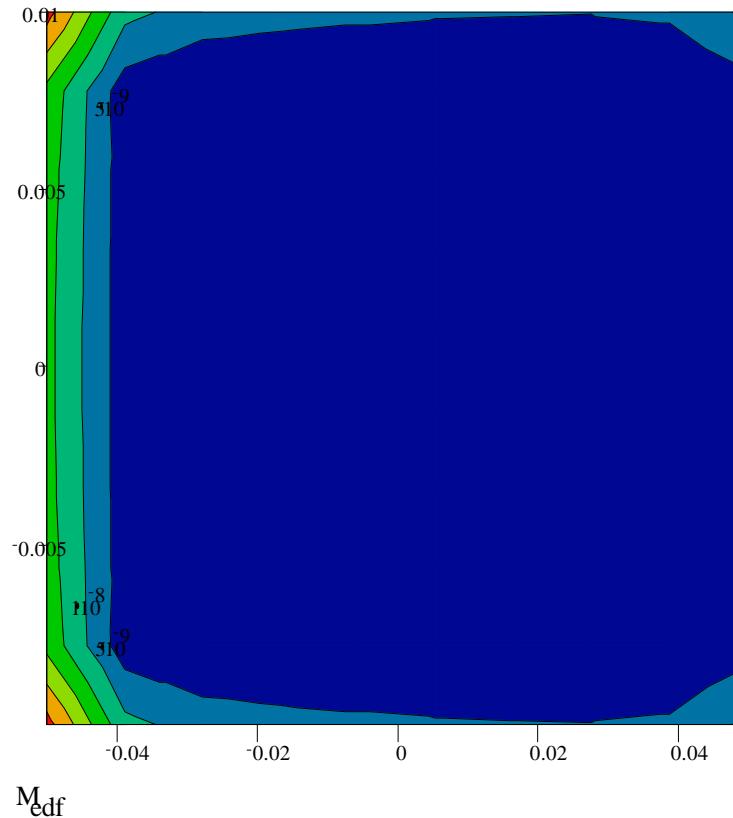


Column Source Results





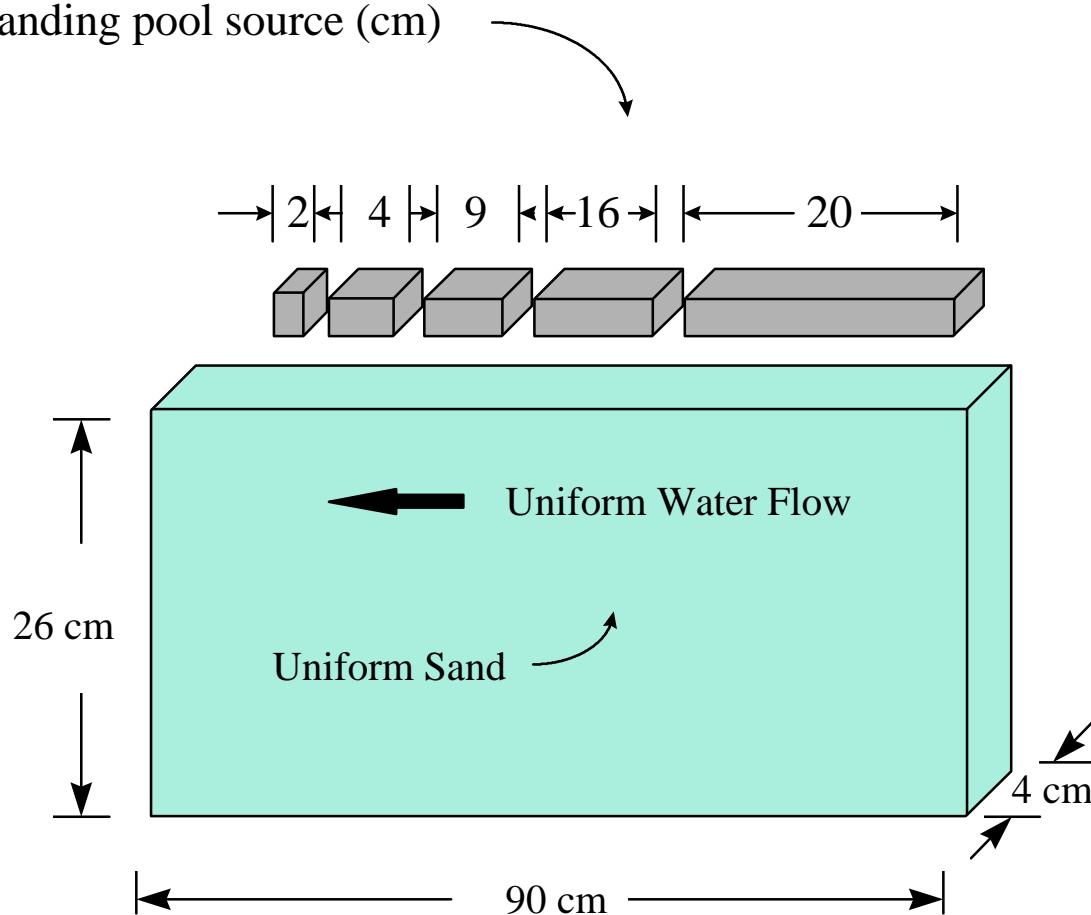
Distribution of mass transfer rates in a NAPL subzone





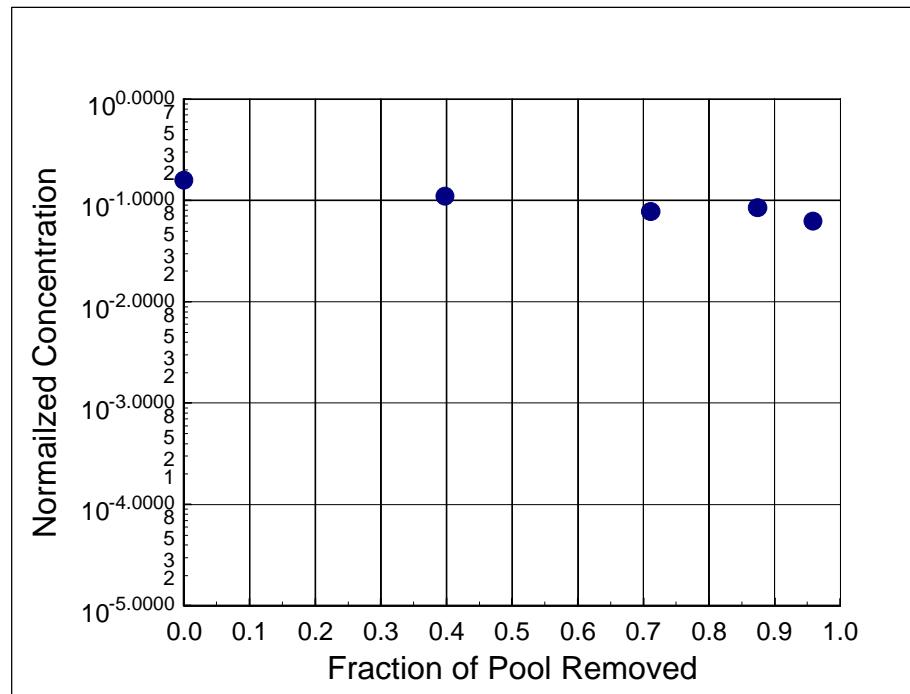
Expanding Pool Laboratory Studies

Location and length of the
expanding pool source (cm)



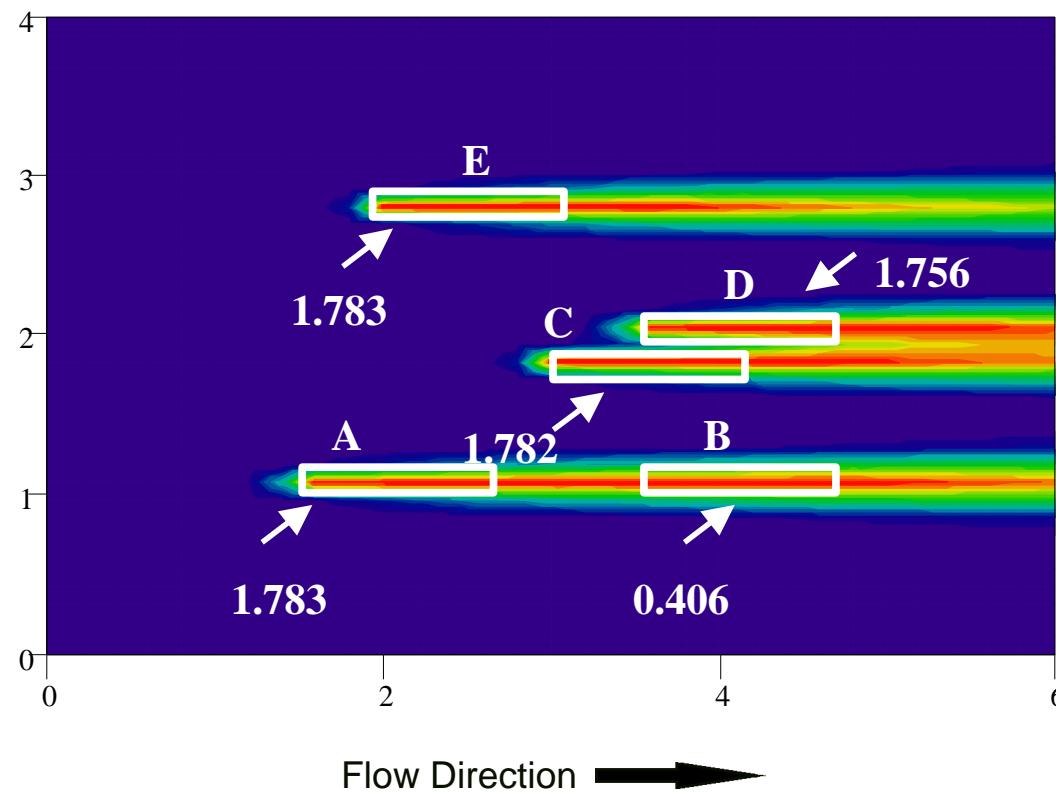


Expanding Pool Results



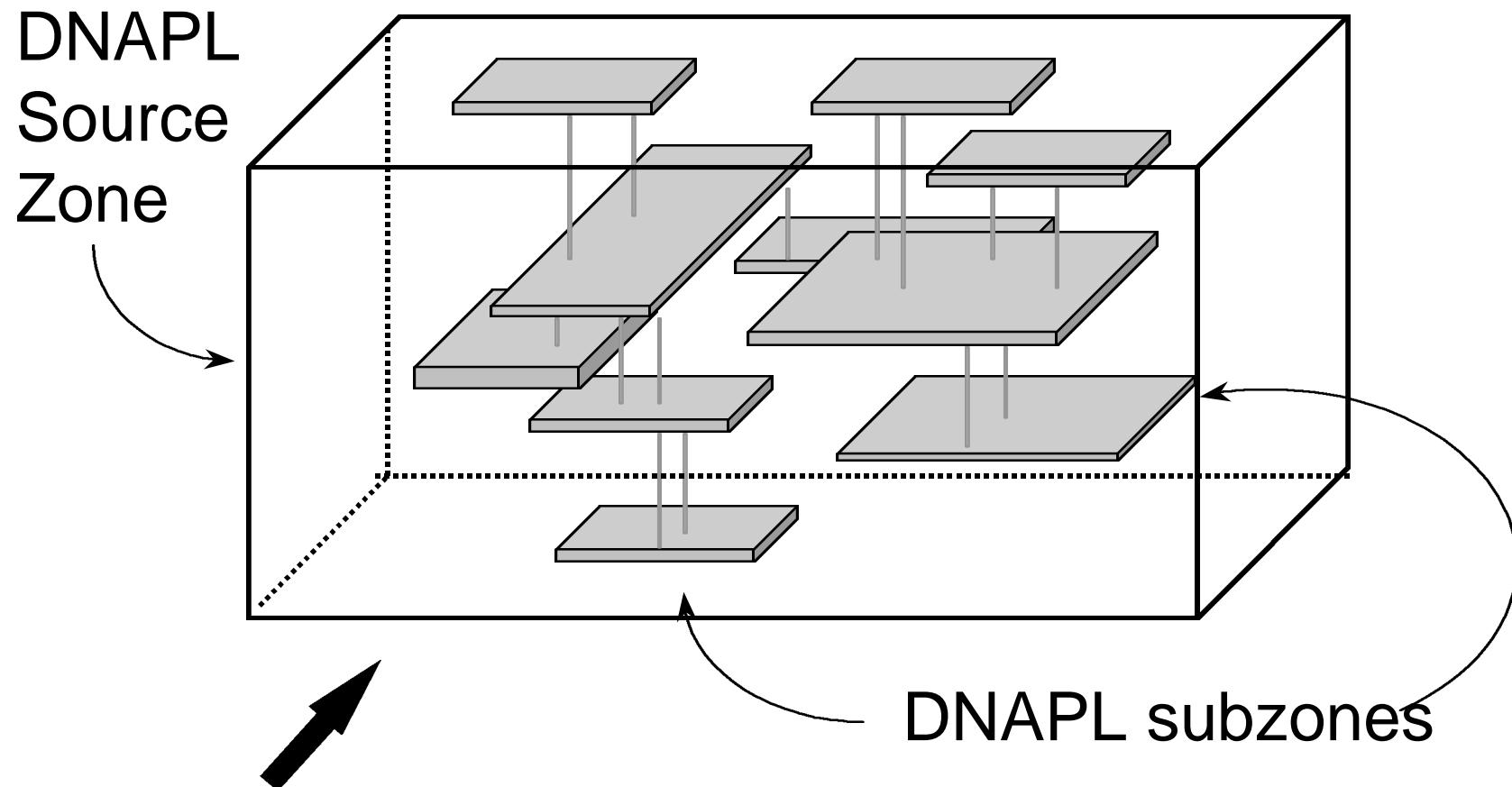


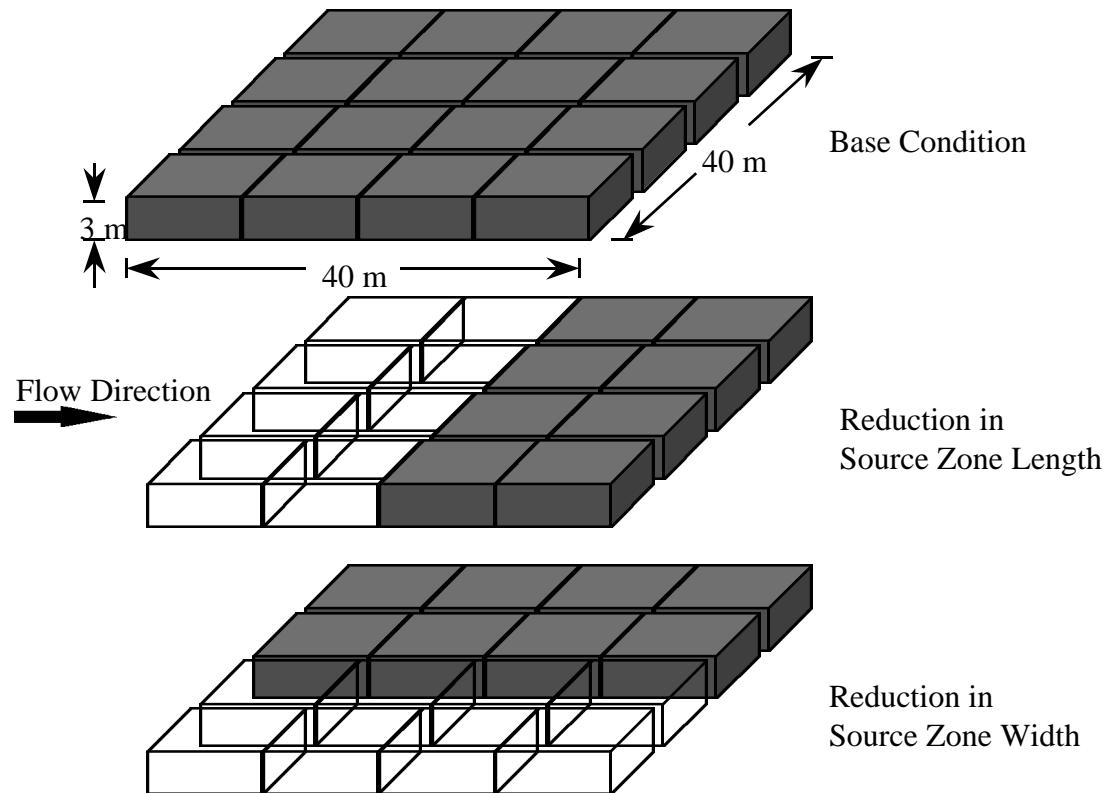
Multiple Pool DNAPL Source Zone



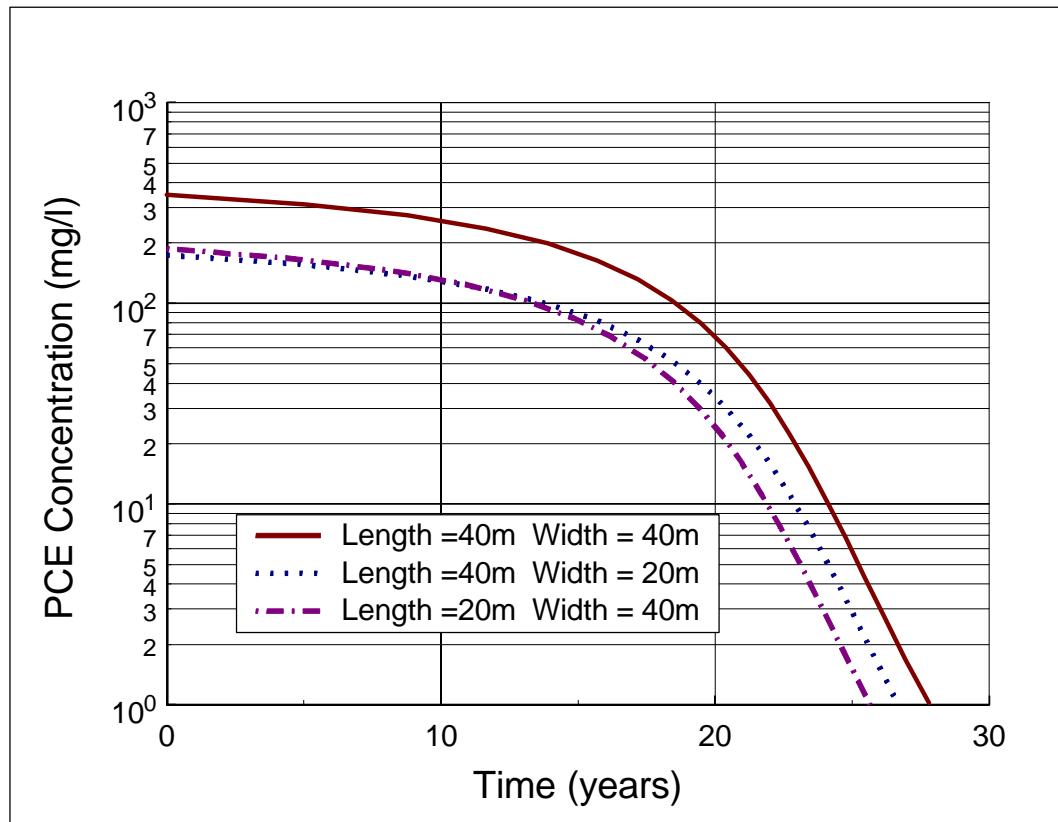


Source Zone Conceptualization





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How Efficient Can it Be?



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**Attainable Mass Depletion and
Associated Cost**

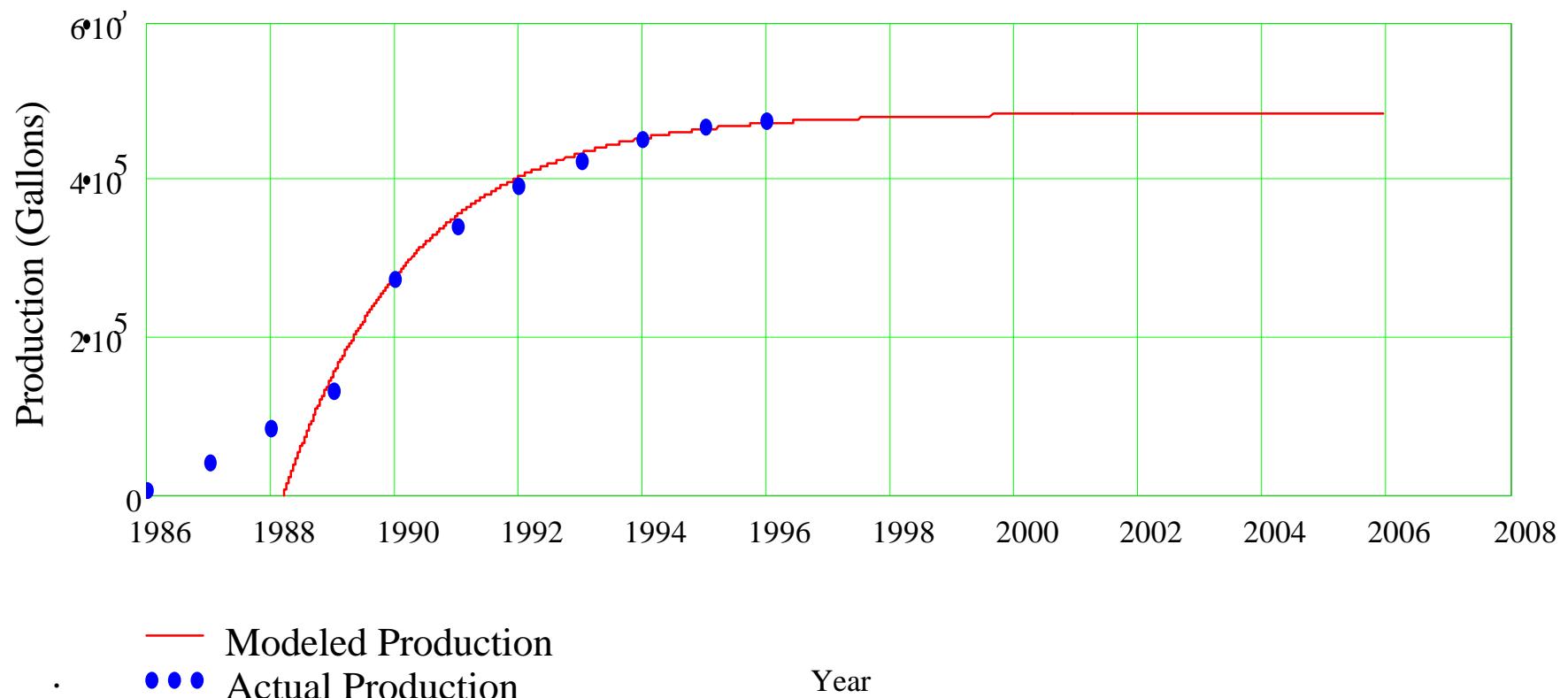


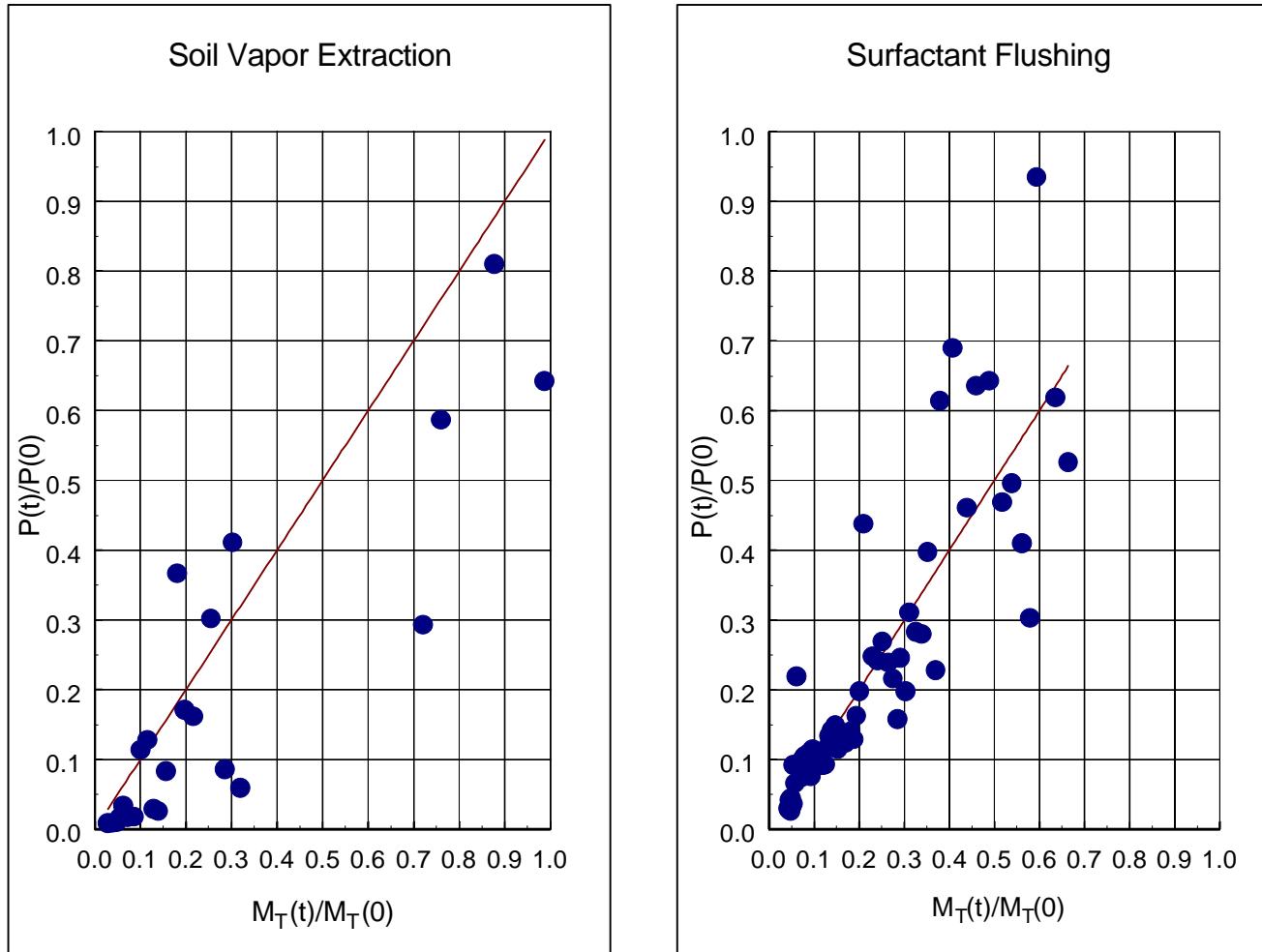
Forced Advection

- **Physical**
 - **Mobil NAPL Recovery**
 - **Soil Vapor Extraction**
 - **Air Sparging**
- **Surfactant/Cosolvent Flushing**
- **Thermal**
 - **Hot water flushing**
 - **Steam (SVE)**
 - **Electrical Heating (SVE)**



What we see



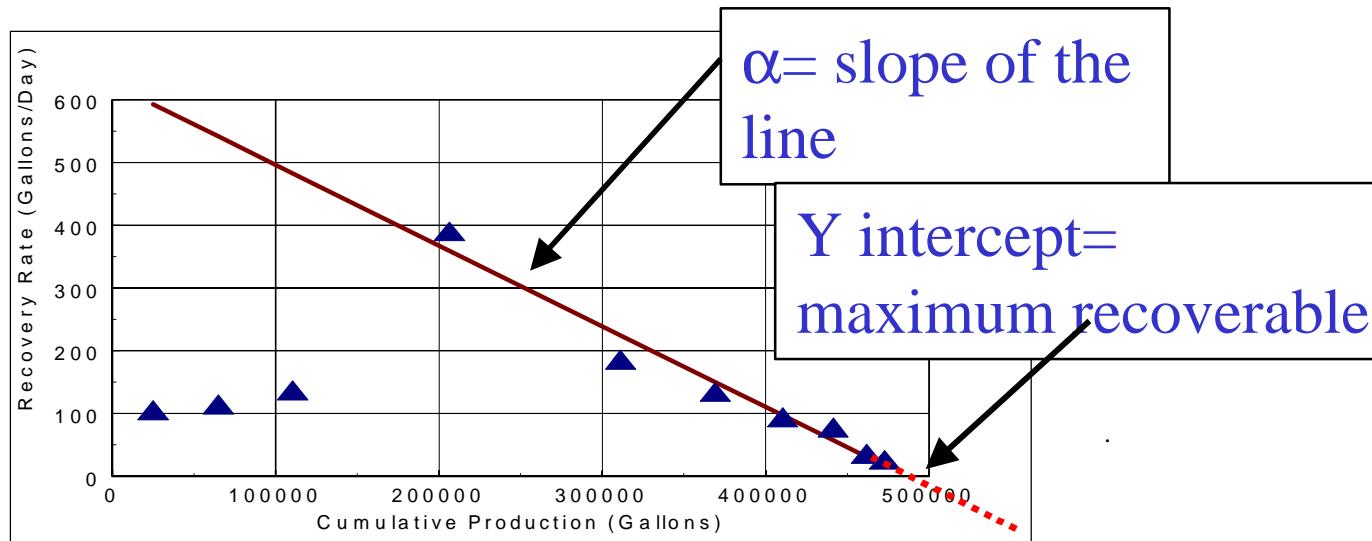




$$P(t) = -a M_{recoverable} e^{-at} \quad (6)$$

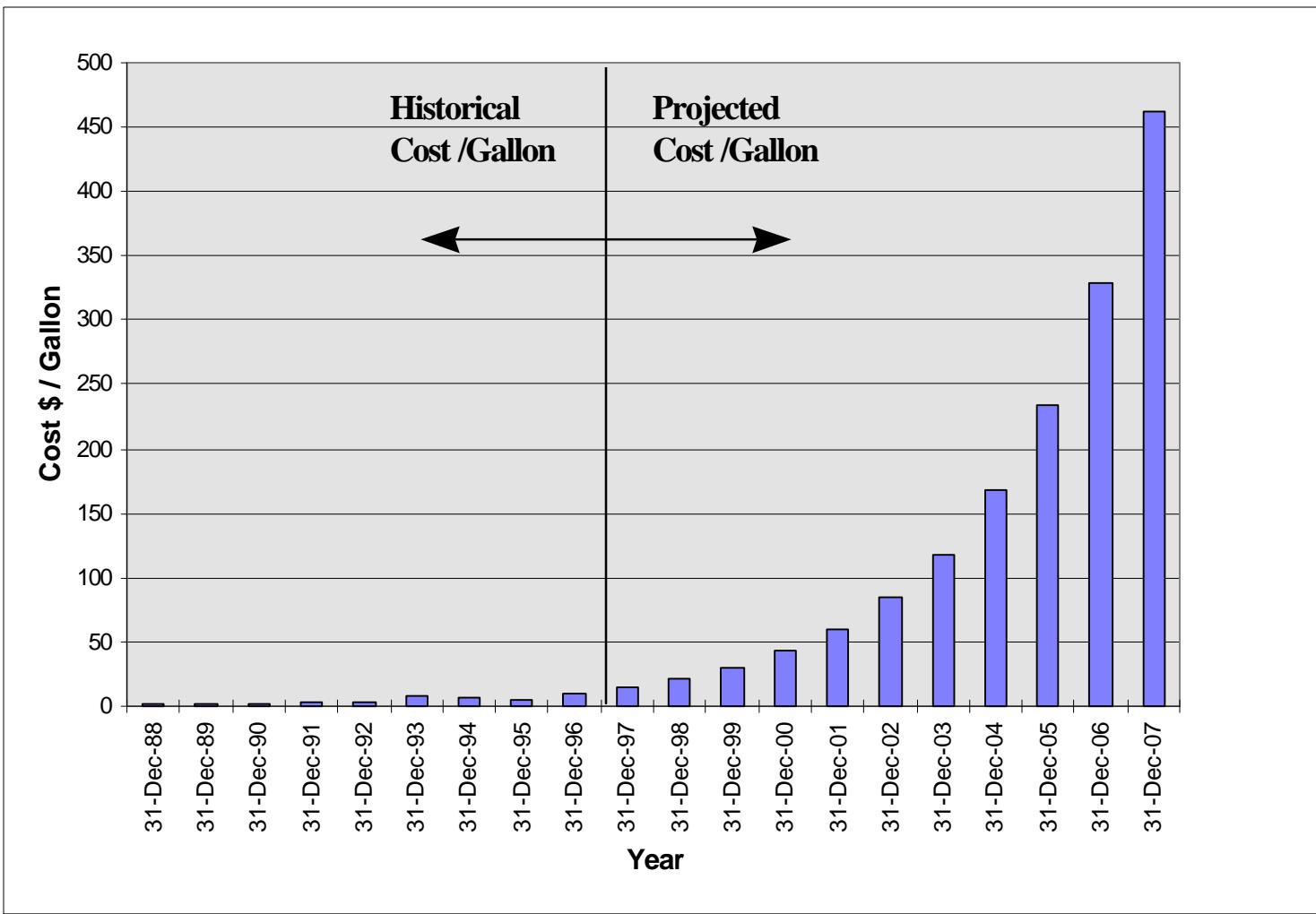
$$M_{remaining}(t) = M_{recoverable} (1 - e^{-at}) \quad (7)$$

$$t_{1/2} = \frac{0.693}{a} \quad (8)$$



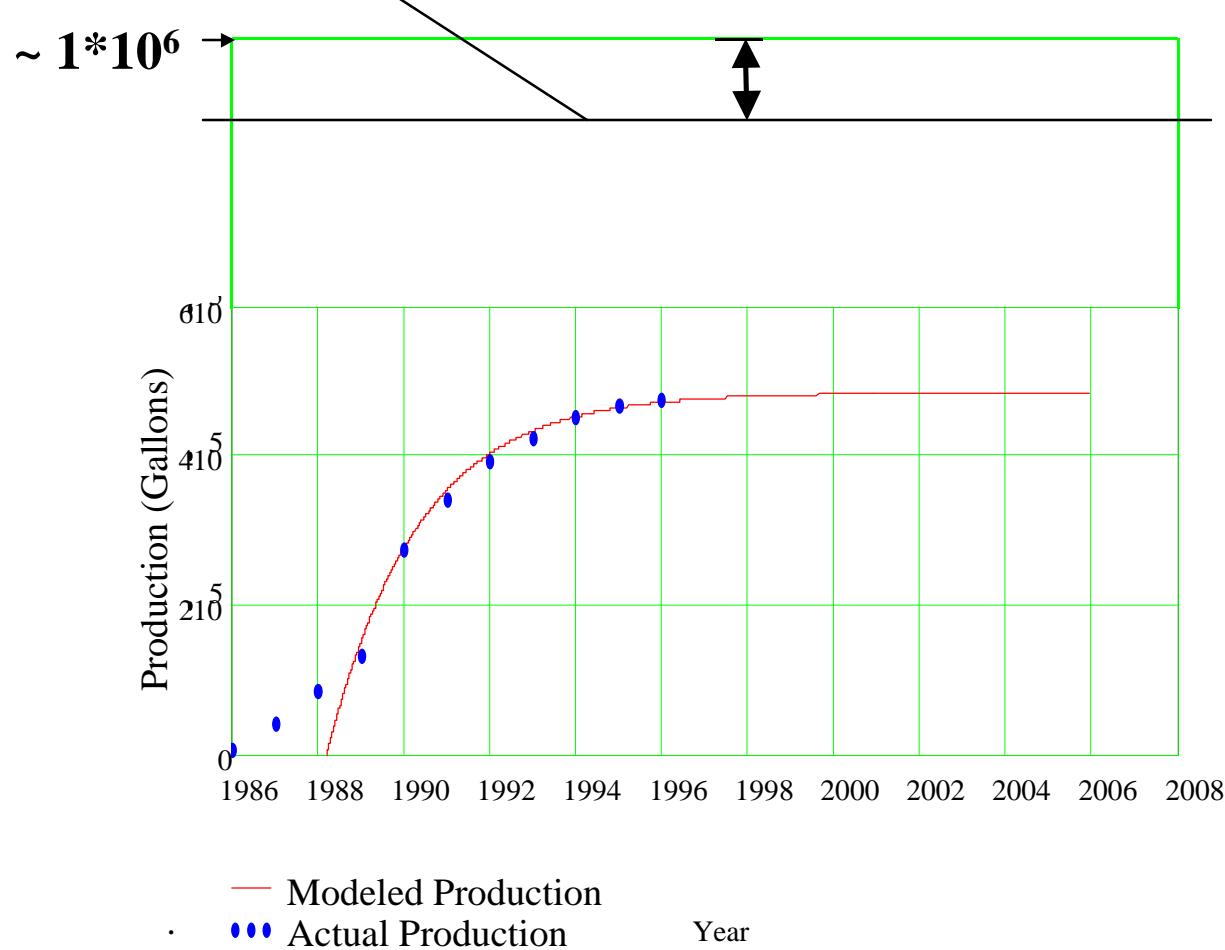


Cost/Gallon as a Function of Time





Goal Line - Amount of depletion required to effect
a meaningful improvement in water quality or reduction
in source longevity





Performance Estimation

$$V_{produced} = E_{Sweep} E_{T\arg et} E_{Techno \log y} V_{initial}$$

$$V_{remaining} = V_{initial} - V_{produced}$$

$$V_{remaining} = V_{initial} (1 - E_{sweep} E_{t\arg et} E_{techno \log y})$$

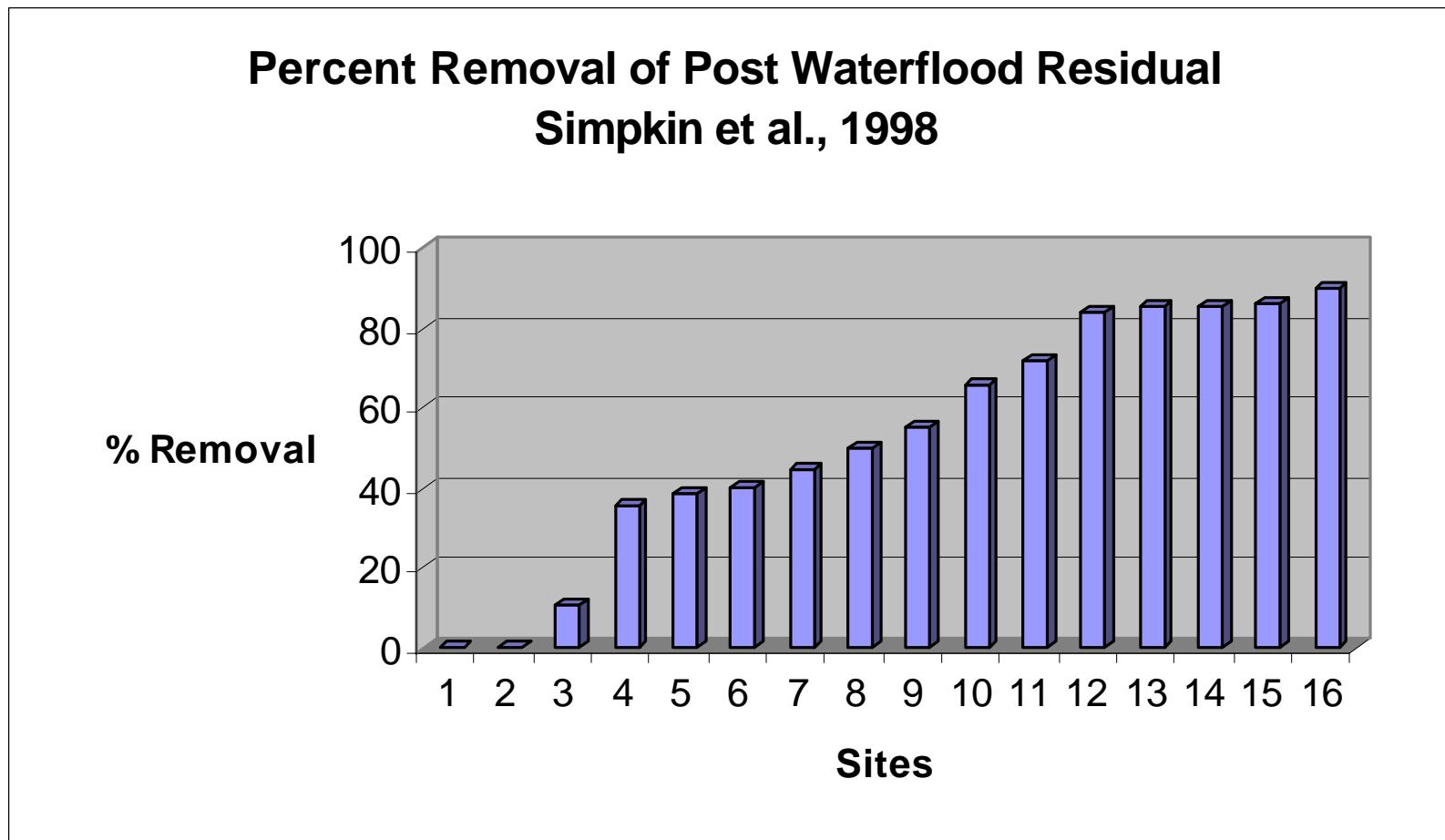
Size matters

Product of efficiencies
always < 1



Surfactant/Cosolvent

$E_{Technology} = 0-90$ (median 53%)





Sweep efficiency between parallel drains in a homogeneous isotropic aquifer $E_{sweep}=1$

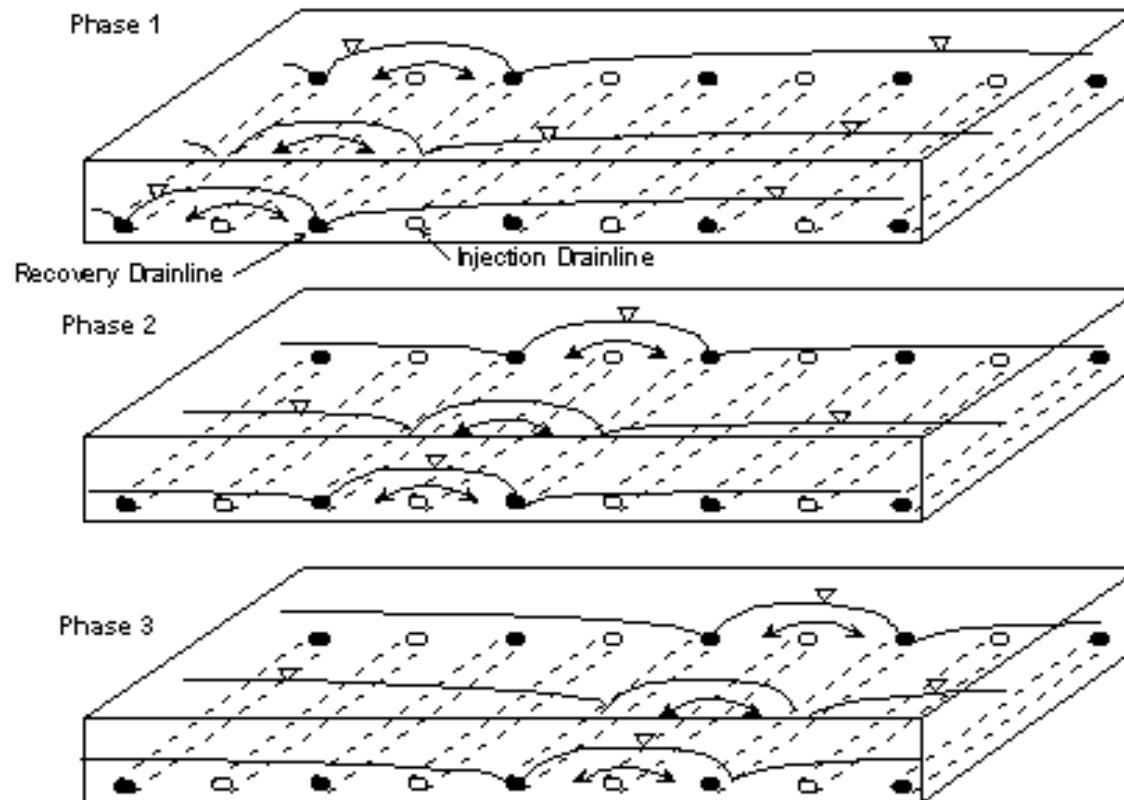


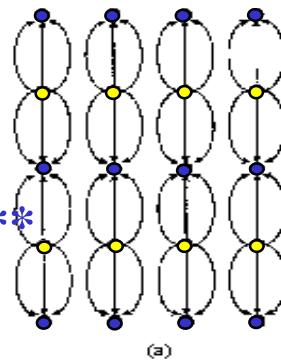
Figure 6-17
Conceptualization of a phased modular implementation approach
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Patterns for well based delivery/recovery systems*

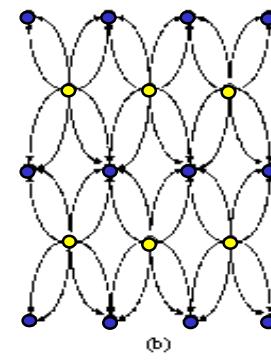
Line Drive

$E_{\text{sweep}} = 0.3-0.9^{**}$



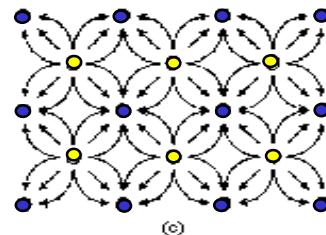
Offset Line Drive

$E_{\text{sweep}} = 0.75-0.92^{**}$



Five Spot

$E_{\text{sweep}} = 0.78^{**}$



Seven Spot

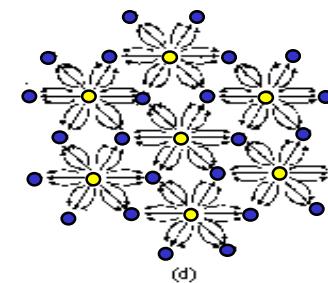


Figure 4-16
Various injection/withdrawal patterns including (a) line drive, (b) offset line drive, (c) five-spot, and (d) seven-spot

*Frick and Taylor (1960)

**Muskat and Wyckoff (1934)



Sample Calc - Mobile NAPL Depletion

$$V_{initial} = 1,000 \text{ gal}$$

$$E_{sweep} = 0.85 \quad E_{technology} = 0.5 \quad E_{target} = 0.95$$

$$V_{remaining} = 600$$

Cost = \$100,000 - 300,000 /acre



Sample Calc - Aggressive NAPL Depletion (e.g. surfactants)

$$V_{initial} = 1,000 \text{ gal}$$

$$E_{sweep} = 0.85 \quad E_{technology} = 0.9 \quad E_{target} = 0.95$$

$$V_{remaining} = 270$$

$$\begin{aligned}\text{Cost}^{**} &= \$500,000 - 7,500,000 / \text{acre} \\ &= \$64 - 588 \text{ yrd}^3 \\ &= \$21 - 239 \text{ gallon}\end{aligned}$$

** Simpkin et al., 1998



Containment Approaches

- **Source Zone**

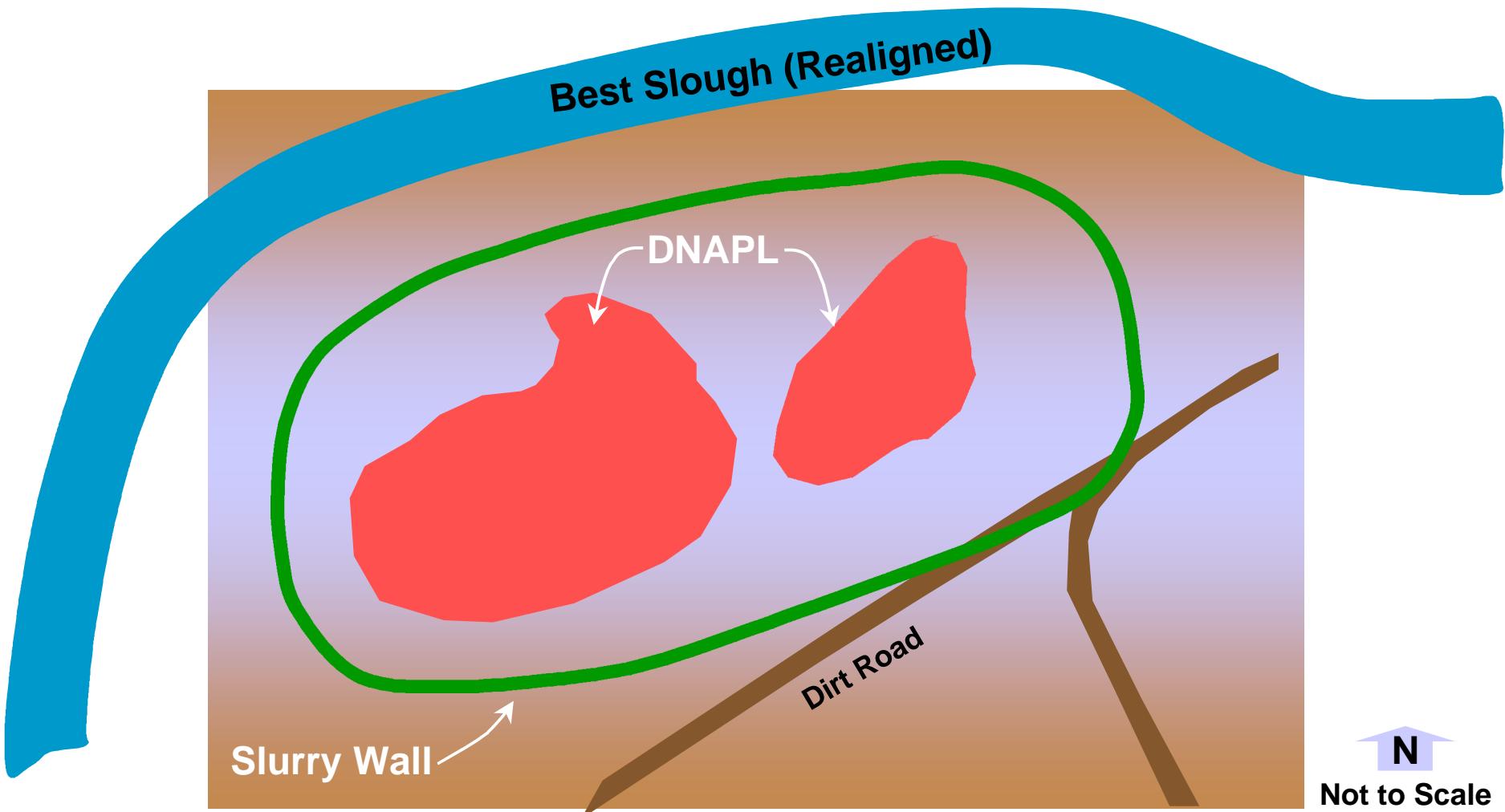
- **Physical barrier**
 - Slurry walls
 - Sheet pile walls
- **Hydraulic barriers**
 - Continuous drains
 - Horizontal wells
- **Reactive barrier**
 - Zero Valent Iron
 - Diffusive Emitters
 - e-barriers

- **Plume Restoration**

- **Source Zone Renovation**
- **Pump and Treat**
- **Natural Attenuation**

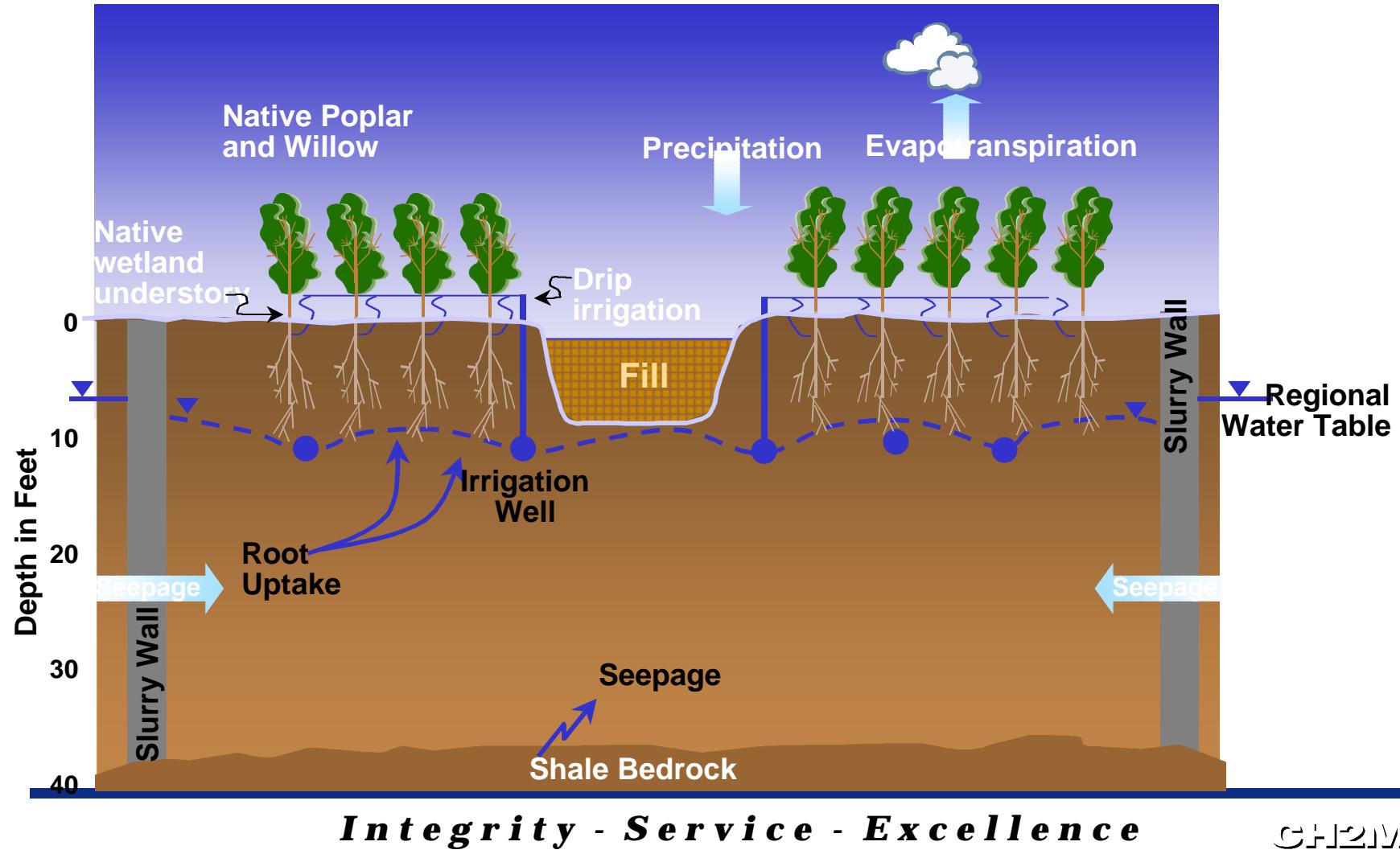


Total Solution: Containment Zone/ Wetlands Enhancement



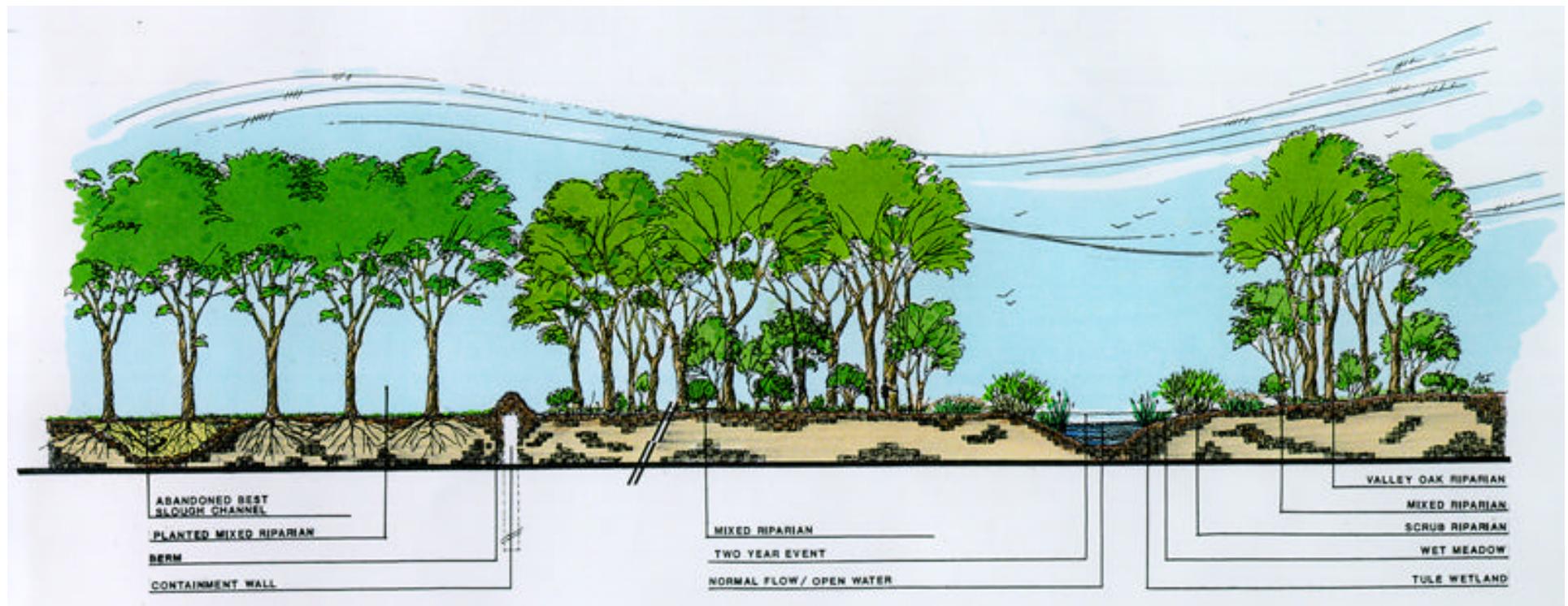


Water Balance (Realigned): Growing Season





Wetlands Enhancement: Concept Section

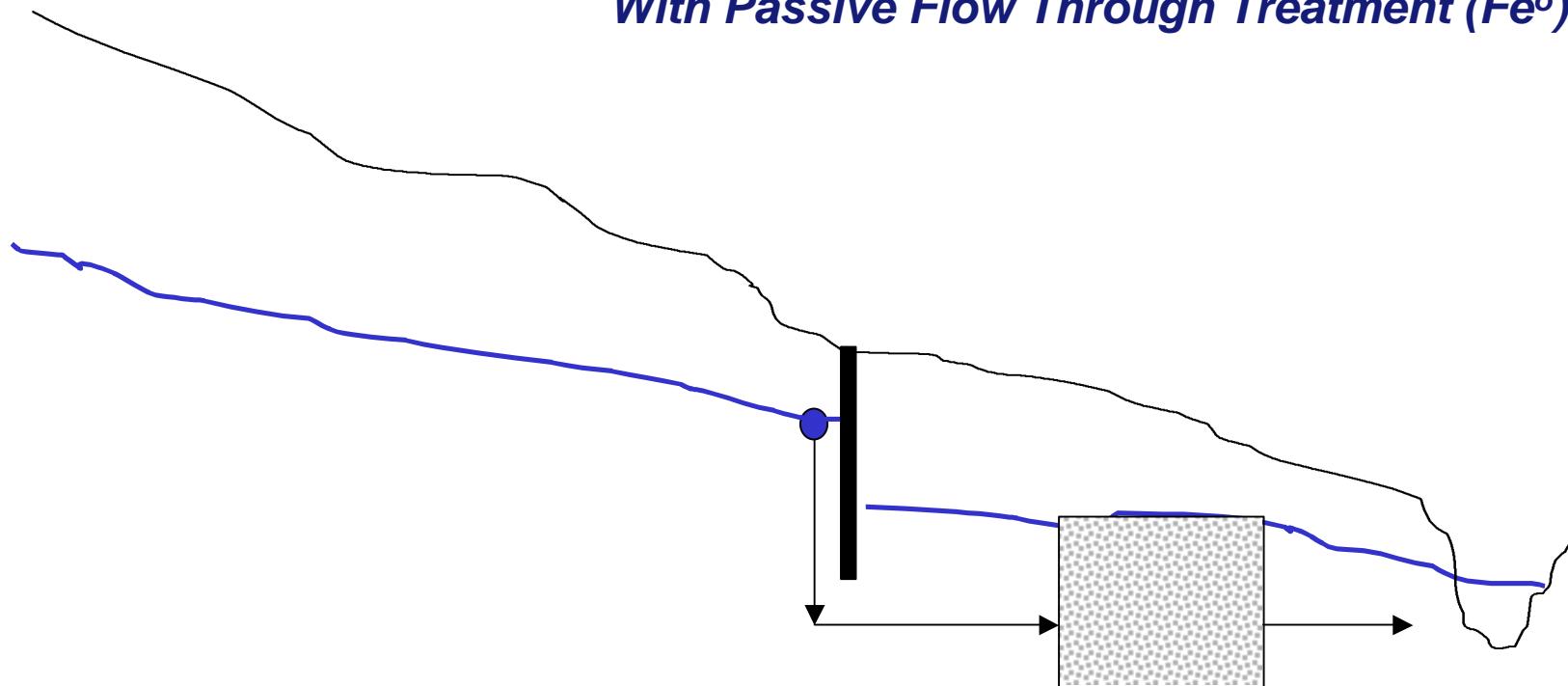




Rocky Flat Mound Plume

Interceptor Trench

With Passive Flow Through Treatment (Fe^o)



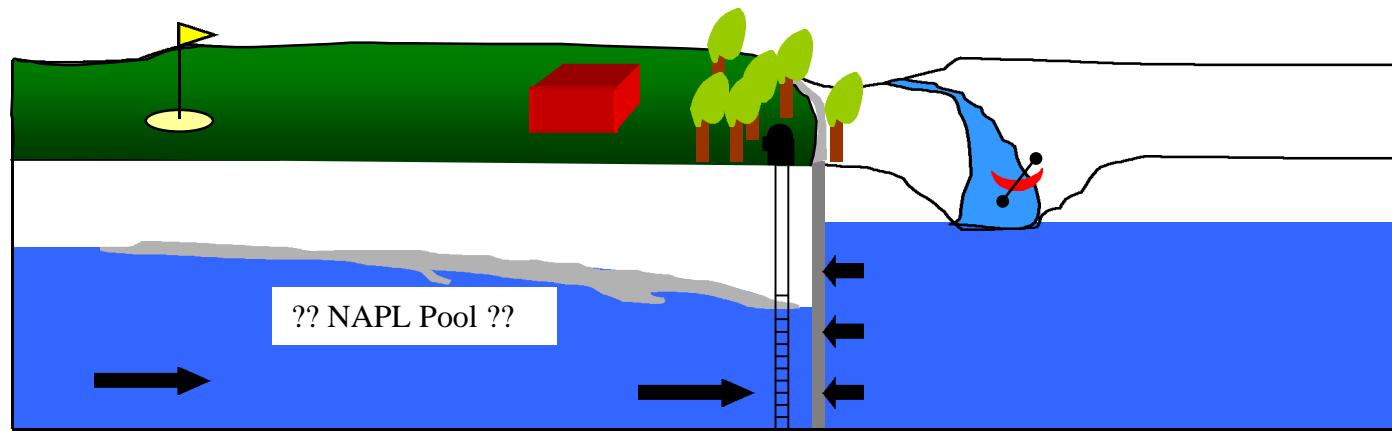


Union Pacific Railroad

- 90 - acre DNAPL zone
- 1.8 million gallons DNAPL recovered
- Coupled Physical - Hydraulic-Physical Containment
 - 10,000 - foot cutoff wall
 - Q ~ 100 gpm
- Phytoremediation
- River Bike Path



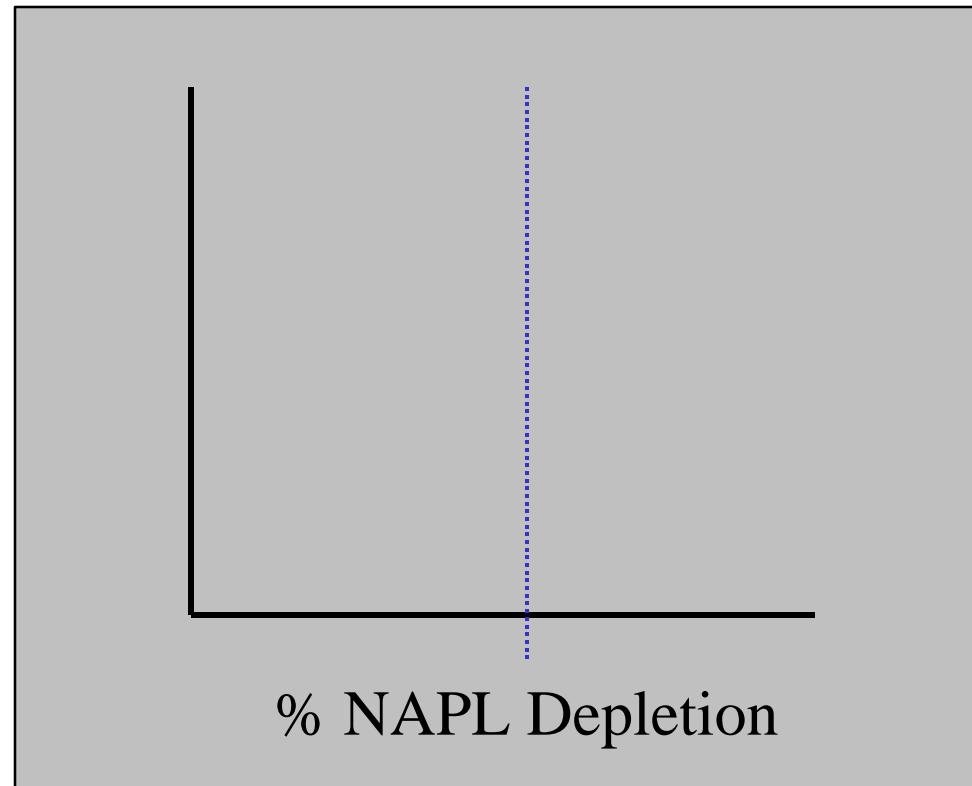
Summary of Key Issues





What is a Pragmatic?

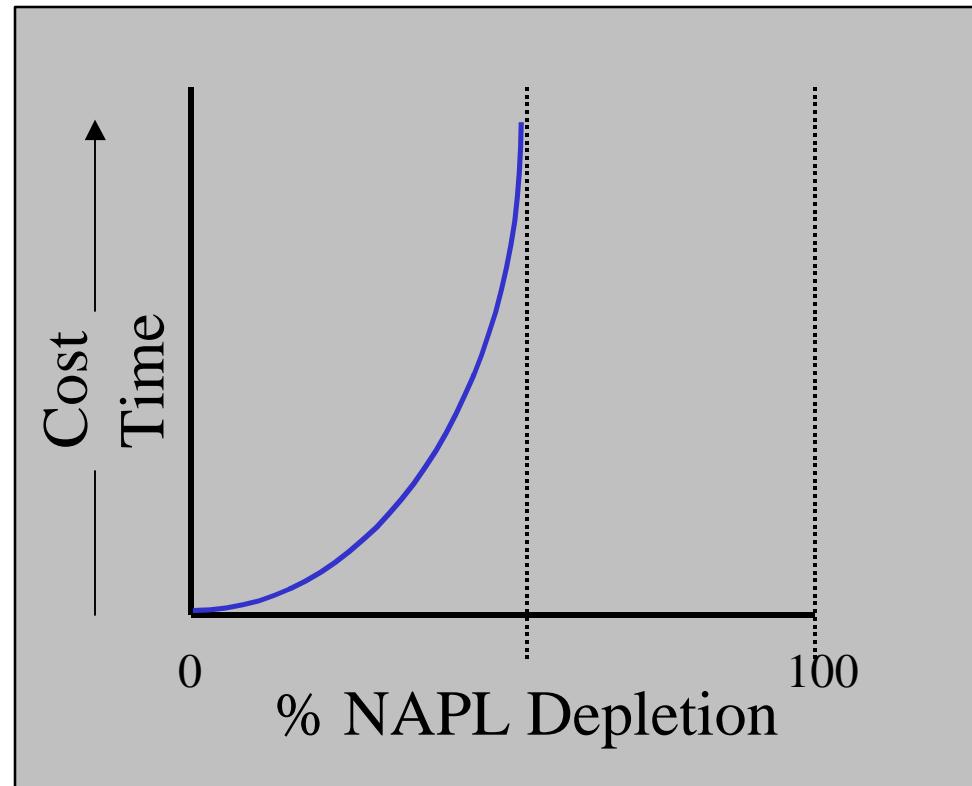
- 1) With proven technology
40-60 % NAPL recovery
appears to be recovery to the
maximum extent possible.





What is Pragmatic?

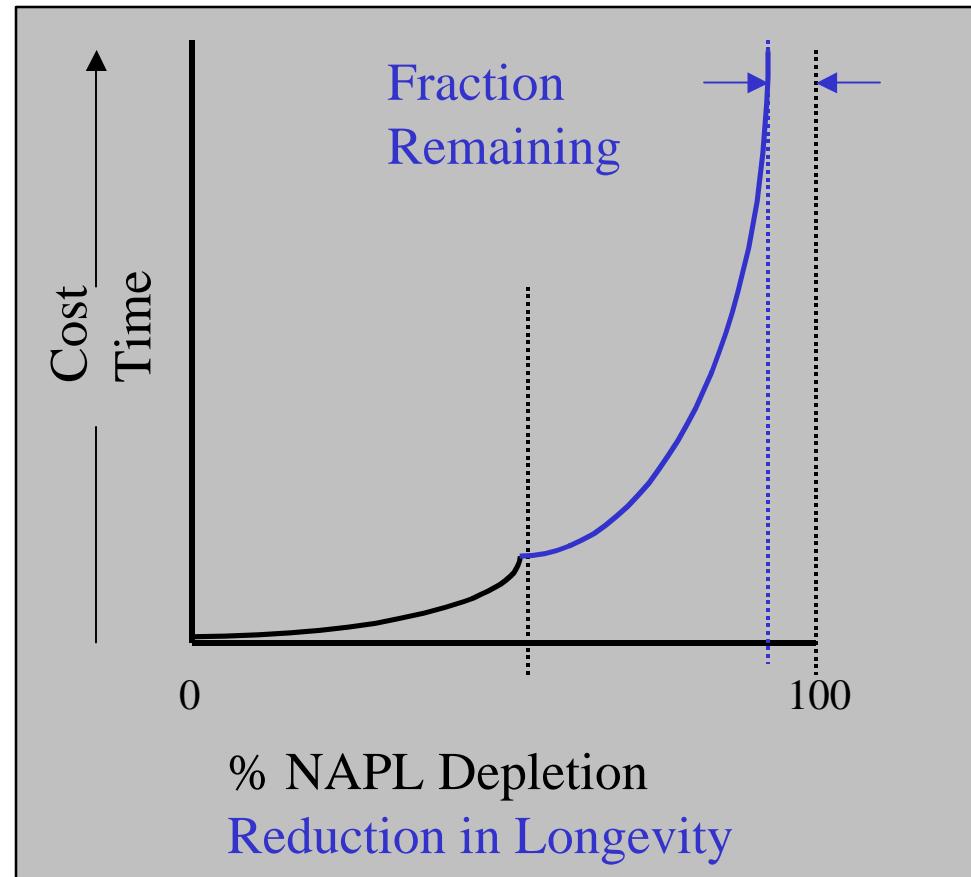
- 1) With proven technology 40-60 % NAPL recovery may be recovery to the maximum extent possible.
- 2) Ultimate depletion will be approached asymptotically with increasing cost and time





What is Pragmatic?

- 1) With proven technology 40-60 % NAPL recovery may be recovery to the maximum extent possible.
- 2) The ultimate depletion will be approached asymptotically with increasing cost.
- 3) With emerging technology even 90% depletion will do little to alter near-term site care requirements, longevity, or risk.
- 4) Lacking clear benefits (and considering potential risks) the cost of emerging technologies are difficult to justify.





Path Forward

Containment

- Done

Renovation Consistent with Reuse

- A reasonable near-term goal

Restoration The Ultimate Goal

- When proven technologies exist